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Modeling perceptual multi-stability with Hodgkin-Huxley neurons

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Perceptual multi-stability can be induced by either using some ambiguous figures (such as Neckar Cube or Face/Vase figure) or showing different images to left and right eyes (binocular rivalry). The observer will experience a persistent switching between different perceptual representations of the same image. The switching process is spontaneous and irregular: time intervals between consequent switching would form some Gaussian-like distribution [1,2]. Switching is highly involuntary and usually human subjects cannot use their "will power" to control the process. Many behavioral experiments have been carried out. Levelt [3,4] found that during binocular rivalry, when the image brightness to one eye increased, the mean duration of perception from the other eye decreased (but little was change on the duration from the same eye). Leopold et al. [5] found that for ambiguous figures, the switching process would slow down if the figure appeared and disappeared periodically.

The neural mechanism of perceptual multi-stability is still unclear. It is possible that perceptual multi-stability is regulated in a similar way like selection process in object-based attention [6]. A very important discovery has been found from EEG recordings: the perception of ambiguous figures seems to correlate with gamma band activity and transient synchrony of some distant brain areas [7-10]. The idea of partial synchronization between a central element and some peripheral elements has been proposed for modeling selective attention [11]. This idea is supported by results of EEG recordings, and there is a strong suggestion that multi-stable perception might also be controlled by the mechanism of partial synchronization.

In the present study, we propose a model of cortical neural network for studying perceptual multi-stability. The model consists of central and peripheral neurons, all of which are modeled by Hodgkin-Huxley equations with synaptic couplings. A dynamical regime is found where initially the central neurons form partial synchronization with one group of peripheral neurons, but after some time, it spontaneously switches to synchronize with another group of peripheral neurons, and then switch back and forth. The model produces a similar Gaussian-like histogram as experimental data. It also meets the constraints observed from various experiments [3-5]. The synchronization occurs in the gamma range, in agreement with EEG findings [7-10].

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